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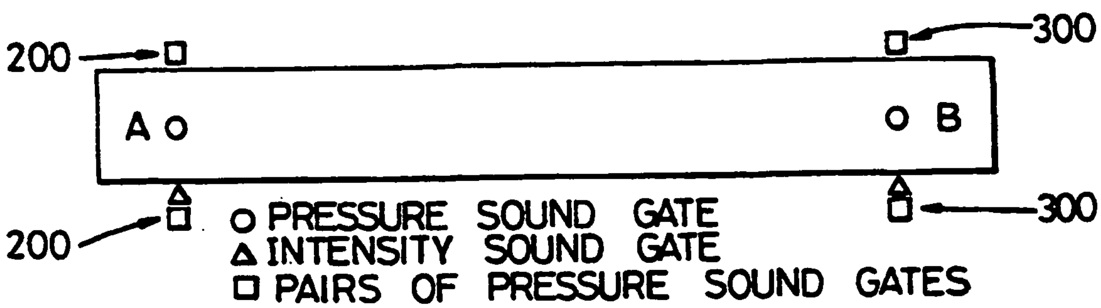

(57) Abstract

An airport noise monitoring system is disclosed comprising a pair of sound detectors (200, 300) installed in and spaced along a runway. A CPU monitors the output of each sound detector so as to recognize an output form from one (200) of the detectors characteristic of an aircraft flying overhead. A flag is assigned to any event giving rise to such an output form indicating the direction of motion of the aircraft, depending on the sound profile from the detector (300) other than the one providing the characteristic output form, and also indicating whether the aircraft is landing, taking off or flying by. Accurate timing and direction information may be obtained and accurately correlated with noise events detected around the airport, to identify noisy flights or carriers.

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AIRPORT NOISE MONITORING SYSTEM

This invention relates to airport noise monitoring systems, i.e. noise monitoring systems which are adapted to distinguish aircraft from other noise events. Once a noise event is attributed to an aircraft, the aircraft is identified from other information, which enables the carrier to be fined if the noise level exceeds an acceptable noise level.

Background to the invention

Airport noise monitoring systems commonly include a number of noise monitoring terminals distributed in and around the airport. Most current airport noise monitors use the technique of "Short Leq" for the acquisition of data, usually based upon a 62.5 ms long basic integration period. Short Leq allows the system to recognize an individual flight by its time history. Of course, not all noise monitoring terminals have a sufficiently good signal-to-noise ratio and in practice, many noise events are lost amongst other noise sources such as heavy vehicles or industrial plant. One measure of the efficiency of an aircraft noise monitoring system is how well it recovers signals in noisy conditions.

Cirrus Research plc produces a noise monitoring terminal which uses efficient aircraft-recognition algorithms. The algorithms are described in A. D. Wallis & R. W. Krug, "The Sydney and Brisbane Noise Terminals", Proc. WESTPRAC, pp. 492-499, Nov. 1991 and basically consist of multiple threshold detection with specified event durations. Experience has proven that this complex nine-parameter algorithm will recognise some 99% of scheduled or military aircraft correctly. In common with all systems, the Cirrus system does have a lower success rate for very quiet aircraft or in areas of high background noise.

With 100 flights per day, the system described above may incorrectly identify one flight per day and thus, before the noise events can be assigned to individual aircraft,

something else must be brought in to reduce this recognition error rate, since at a major airport with over 1000 flights per day, even a 99% success rate is unacceptable.

Each airport has access to flight information - as displayed on the internal information boards - and this is often used as one of the correlation parameters in identification. However, if the airport has significant general aviation or private traffic, this information will be incomplete and significant events such as jet test flights will not be included. Thus, knowing that a noise event has taken place and that there was an incoming or outgoing flight at a similar time is still not adequate to enable the two to be correlated with a sufficient degree of confidence. The flight information data must be tied to a particular noise event with no significant possibility of error.

Summary of the invention

According to the present invention, a true take-off or landing time is attributed to each flight by appropriate sound detectors, and whether the aircraft is taking off or landing is recognised. An airport noise monitoring system according to the present invention comprises a pair of sound detectors to be installed in or on and spaced along a runway and means for monitoring the output of each sound detector so as to recognize an output form from either one of the detectors characteristic of an aircraft flying overhead, checking the output from the other sound detector representing time prior to and subsequent to the event giving rise to the characteristic output form for an output form indicative of the proximity of an aircraft and consequently assigning to the event a flag indicative of the direction of motion of the aircraft and whether it is taking off, flying by or landing. The output form from either of the detectors characteristic of an aircraft flying overhead may be recognized by the nine-parameter algorithm as discussed above.

Having sound detectors placed in or on the runway and recognizing and timing the passage of aircraft provides accurate information as to take-off or landing times, which may then be correlated with noise events detected by monitoring terminals elsewhere with a reasonable degree of certainty. The data from the sound detectors are now used in place of the airport flight time information to give a good event definition and only then is the flight time information added to enable individual flights to be recognised. In effect, the flight time information is required only to indicate the order in which the aircraft take off or land, rather than the exact time.

Preferably, the means for monitoring, checking and assigning is adapted to assign to the event a flag indicating that the direction of motion of the aircraft is away from the said one sound detector and towards the said other sound detector when the output from the said other sound gate includes an output form indicative of the proximity of an aircraft within a predetermined window of time subsequent to the event. Further, the means for monitoring, checking and assigning is preferably adapted to assign to the event a flag indicating that the aircraft is landing when the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead. When the said output form indicative of the proximity of an aircraft is characteristic of an aircraft flying overhead, the means for monitoring, checking and assigning will preferably assign to the event a flag indicating that the aircraft is flying by. The output form indicative of the proximity of an aircraft may be any output exceeding a predetermined noise level.

Similarly, the means for monitoring, checking and assigning is preferably adapted to assign to the event a flag indicating that the direction of motion of the aircraft is towards the said one sound detector and away from the said other sound detector when the output from the said other

sound gate includes an output form indicative of the proximity of an aircraft within a predetermined window of time prior to the event. Further, the means for monitoring, checking and assigning is preferably adapted to assign to the event a flag indicating that the aircraft is taking off when the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead. Any output from the said other sound detector which has already been taken into account in assigning a flag indicative of the direction of motion of an aircraft giving rise to a previous event will preferably be disregarded by the means for monitoring, checking and assigning.

The noise monitoring system may further include a plurality of further sound detectors to be distributed in or around the airport and including means for monitoring the output of each noise detector so as to recognize an output form characteristic of an aircraft flying overhead and for correlating the events and flags recognized and assigned by the means for monitoring, checking and assigning with events giving rise to the characteristic output forms recognized by the means for monitoring the output of each further sound detector.

The means for monitoring the output of each further sound detector and/or the means for monitoring, checking and assigning may comprise one or more suitably programmed microprocessors.

The present invention also extends to a method of detecting an aircraft comprising monitoring the output of each of a pair of sound detectors installed in or on and spaced along a runway so as to recognize an output form from either one of the detectors characteristic of an aircraft flying overhead, checking the output from the other sound detector representing time prior to and subsequent to the event giving rise to the characteristic output form for an output form indicative of the proximity of an aircraft and

assigning to an event giving rise to such a characteristic output form a flag indicative of the direction of motion of the aircraft and whether it is taking off, flying by or landing in dependence upon the output from the said other sound detector.

The method may include checking the output from the said other sound detector within a predetermined window of time subsequent to the event and assigning to the event a flag indicating that the direction of motion of the aircraft is away from the said one sound detector and towards the said other sound detector if that output includes an output form indicative of the proximity of an aircraft. In these circumstances, the method preferably includes assigning to the event a flag indicating that the aircraft is landing if the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead. Further, the method preferably includes assigning to the event a flag indicating that the aircraft is flying by if the said output form indicative of the proximity of an aircraft is characteristic of an aircraft flying overhead.

The method may include checking the output from the said other sound detector within a predetermined window of time prior to the event and assigning to the event a flag indicating that the direction of motion of the aircraft is towards the said one sound detector and away from the said other sound detector if that output includes an output form indicative of the proximity of an aircraft. In these circumstances, the method preferably includes assigning to the event a flag indicating that the aircraft is taking off if the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead. Preferably, any output from the said other sound detector which has already been taken into account in assigning a flag indicative of the direction of motion of an aircraft giving rise to a previous event is disregarded.

The method may further include monitoring the output of each of a plurality of further sound detectors distributed in or around the airport so as to recognize an output form characteristic of an aircraft flying overhead and correlating the events and flags recognized and assigned by monitoring and checking the outputs of the said pair of sound detectors with events giving rise to the characteristic output forms recognized by monitoring the output of each further sound detector.

The monitoring of the output of each further sound detector and/or the monitoring and checking of the output of the said pair of sound detectors and consequent assignment of flags may be accomplished by one or more suitably programmed microprocessors.

Brief description of the drawings

The present invention will now be described by way of example with reference to the accompanying drawings in which:

Fig. 1 illustrates a simple sound detector with one pressure transducer;

Fig. 2 illustrates a more complex sound detector with provision for intensity measurement;

Fig. 3 is a schematic illustration of a runway with sound detectors installed;

Fig. 4 is a schematic illustration of the output from the two sound detectors when an aircraft is taking off; and

Fig. 5 is a corresponding illustration when the aircraft is landing.

Detailed description

The simple noise detector 10 illustrated in fig. 1 includes a pressure transducer 12, which in this example is a microphone. The output from the microphone is passed through a band-pass filter 14, which removes unwanted frequencies, leaving those which are generated by aircraft engines and provide the highest signal-to-noise ratio. The filtered signal then passes through a squarer 16 and is integrated by an integrator 18, operating over a 62.5 ms cycle, to provide a series of pulses representing the mean square average sound level during the preceding 62.5 ms. These pulses are digitised and stored in a memory or store 20 to be processed by a CPU 22 as described.

A more complex noise detector 110 is illustrated in fig. 2, including a pair of microphones 112, 114. The signals from the microphones are summed at 116 and 118, with one summation circuit 118 having the output from one microphone 114 inverted by inverter 120, thus outputting the difference between the two microphone signals. The signals pass through respective band-pass filters 122, 124 as described above and are then processed by an integrator 126, a pre-processor 128 and a CPU 130 to yield intensity, sound power and directionality information in the usual way. Again, a series of digitised pulses is stored in a memory or store 132 to be processed by a suitably programmed CPU 134.

Fig. 3 illustrates schematically the placement of the sound detectors on a runway. As can be seen, one sound detector 200 or possibly a pair of sound detectors 200 is placed at one end A of the runway and another sound detector 300 or pair of sound detectors 300 is placed at the other end B. Where a single detector is emplaced at each end of the runway, it is preferred that it be embedded in the runway surface. The separate detectors 200; 300 or pairs of detectors 200; 300 are able by virtue of their spacing along the runway to resolve the position of the aircraft at various times as it flies overhead and therefore determine its direction of flight.

Fig. 4 illustrates diagrammatically a typical output from two sound detectors 200; 300 positioned at points A and B on or in the runway when an aircraft is taking off in the direction A-B. As the aircraft taxis into place at one and A of the runway, the associated sound detector 200 detects the increased level of sound. However, the character of the sound detected by this detector 200 is quite different from that attributable to an aircraft passing overhead and accordingly, the sound level is simply stored in memory for future reference. As the aircraft begins its run along the runway, the sound level detected by the detector 200 diminishes with a characteristic slope. Although this slope could be used as a trigger for an attributable event, this is not preferred owing to inherent differences in the take-off patterns of various aircraft and flights and the fact that incoming aircraft could be mistaken for aircraft beginning their take-off. Rather, the characteristically diminishing sound level is again stored for future reference.

Once the aircraft has travelled sufficiently far down the runway, it takes off and subsequently passes over the second sound detector 300. The output from this detector 300 will have a form characteristic of an aircraft flying overhead and will be recognised as such by the processing electronics, i.e. the microprocessor. The recognition algorithm is as described above. Once this characteristic form has been recognised, the CPU will refer back to the stored sound levels from the first detector 200 within a predetermined window of time preceding the event at the second detector 300 and in doing so will encounter the high level of sound terminating in a characteristic slope. This will be recognised as indicating the presence of an aircraft at the first detector 200, and perhaps even the fact that it is beginning its take-off. Accordingly, this event will be timed and flagged as a take-off in the direction A-B.

Fig. 5 illustrates diagrammatically a typical output from two sound detectors 200; 300 positioned at points A and B on or in the runway when an aircraft is landing in the direction A-B. As the aircraft passes over the first sound detector 200, the output from this detector 200 will have a form characteristic of an aircraft flying overhead and will be recognised as such by the processing electronics, i.e. the microprocessor. Again, the recognition algorithm is as described above. Once this characteristic form has been recognised, the CPU will refer back to stored sound levels from the second detector 300 within a predetermined window of time preceding the event at the second detector 300 and in doing so will be unable to identify a high level of sound, which has not already been attributed to a previous event, indicating the presence of an aircraft at the second detector 300. Accordingly, the CPU will wait until the beginning of predetermined window of time and then inspect the output from the second detector.

After landing, the aircraft will run or taxi by the second detector 300, which detects the increased level of sound. The character of the sound detected by this detector 300 is quite different from that attributable to an aircraft passing overhead and accordingly, provided this sound level coincides with the window of time following the event at the first detector 200, this event will be timed and flagged as a landing in the direction A-B. In the unlikely event that both detectors show characteristic forms attributable to an aircraft flying overhead within the predetermined window of time from one another, the event will be flagged as a fly-by or abortive landing in the relevant direction.

Once the take-offs and landings are accurately timed and flagged, they may be correlated with high confidence levels with noise events detected by other noise monitoring stations in and around the airport, and the flights in question identified from airport information which is used

to determine the order in which particular flights took off and landed.

CLAIMS

1. An airport noise monitoring system comprising a pair of sound detectors to be installed in or on and spaced along a runway and means for monitoring the output of each sound detector so as to recognize an output form from either one of the detectors characteristic of an aircraft flying overhead, checking the output from the other sound detector representing time prior to and subsequent to the event giving rise to the characteristic output form for an output form indicative of the proximity of an aircraft and consequently assigning to the event a flag indicative of the direction of motion of the aircraft and whether it is taking off, flying by or landing.

2. A noise monitoring system according to claim 1 in which the means for monitoring, checking and assigning is adapted to assign to the event a flag indicating that the direction of motion of the aircraft is away from the said one sound detector and towards the said other sound detector when the output from the said other sound gate includes an output form indicative of the proximity of an aircraft within a predetermined window of time subsequent to the event.

3. A noise monitoring system according to claim 2 in which the means for monitoring, checking and assigning is adapted to assign to the event a flag indicating that the aircraft is landing when the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead.

4. A noise monitoring system according to claim 2 or claim 3 in which the means for monitoring, checking and assigning is adapted to assign to the event a flag indicating that the aircraft is flying by when the said output form indicative of the proximity of an

aircraft is characteristic of an aircraft flying overhead.

5. A noise monitoring system according to any preceding claim in which the means for monitoring, checking and assigning is adapted to assign to the event a flag indicating that the direction of motion of the aircraft is towards the said one sound detector and away from the said other sound detector when the output from the said other sound gate includes an output form indicative of the proximity of an aircraft within a predetermined window of time prior to the event.

6. A noise monitoring system according to claim 5 in which the means for monitoring, checking and assigning is adapted to assign to the event a flag indicating that the aircraft is taking off when the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead.

7. A noise monitoring system according to claim 5 or claim 6 in which the means for monitoring, checking and assigning is adapted to disregard any output from the said other sound detector which has already been taken into account in assigning a flag indicative of the direction of motion of an aircraft giving rise to a previous event.

8. A noise monitoring system according to any preceding claim further including a plurality of further sound detectors to be distributed in or around the airport and including means for monitoring the output of each noise detector so as to recognize an output form characteristic of an aircraft flying overhead and for correlating the events and flags recognized and assigned by the means for monitoring, checking and assigning with events giving rise to the characteristic output forms recognized by the means

for monitoring the output of each further sound detector.

9. A noise monitoring system according to any preceding claim in which the means for monitoring the output of each further sound detector comprises one or more suitably programmed microprocessors.

10. A noise monitoring system according to any preceding claim in which the means for monitoring, checking and assigning comprises one or more suitably programmed microprocessors.

11. A method of detecting an aircraft comprising monitoring the output of each of a pair of sound detectors installed in or on and spaced along a runway so as to recognize an output form from either one of the detectors characteristic of an aircraft flying overhead, checking the output from the other sound detector representing time prior to and subsequent to the event giving rise to the characteristic output form for an output form indicative of the proximity of an aircraft and assigning to an event giving rise to such a characteristic output form a flag indicative of the direction of motion of the aircraft and whether it is taking off, flying by or landing in dependence upon the output from the said other sound detector.

12. A method according to claim 11 including checking the output from the said other sound detector within a predetermined window of time subsequent to the event and assigning to the event a flag indicating that the direction of motion of the aircraft is away from the said one sound detector and towards the said other sound detector if that output includes an output form indicative of the proximity of an aircraft.

13. A method according to claim 12 including assigning to the event a flag indicating that the aircraft is

landing if the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead.

14. A method according to claim 12 or claim 13 including assigning to the event a flag indicating that the aircraft is flying by if the said output form indicative of the proximity of an aircraft is characteristic of an aircraft flying overhead.

15. A method according to any one of claims 11-14 including checking the output from the said other sound detector within a predetermined window of time prior to the event and assigning to the event a flag indicating that the direction of motion of the aircraft is towards the said one sound detector and away from the said other sound detector if that output includes an output form indicative of the proximity of an aircraft.

16. A method according to claim 15 including assigning to the event a flag indicating that the aircraft is taking off if the said output form indicative of the proximity of an aircraft is not characteristic of an aircraft flying overhead.

17. A method according to claim 15 or claim 16 in which any output from the said other sound detector which has already been taken into account in assigning a flag indicative of the direction of motion of an aircraft giving rise to a previous event is disregarded.

18. A method according to any one of claims 11-17 further including monitoring the output of each of a plurality of further sound detectors distributed in or around the airport so as to recognize an output form characteristic of an aircraft flying overhead and correlating the events and flags recognized and

assigned by monitoring and checking the outputs of the said pair of sound detectors with events giving rise to the characteristic output forms recognized by monitoring the output of each further sound detector.

19. A method according to claim 18 in which the monitoring of the output of each further sound detector is accomplished by one or more suitably programmed microprocessors.

20. A method according to any one of claims 10-19 in which the monitoring and checking of the output of the said pair of sound detectors and consequent assignment of flags is accomplished by one or more suitably programmed microprocessors.

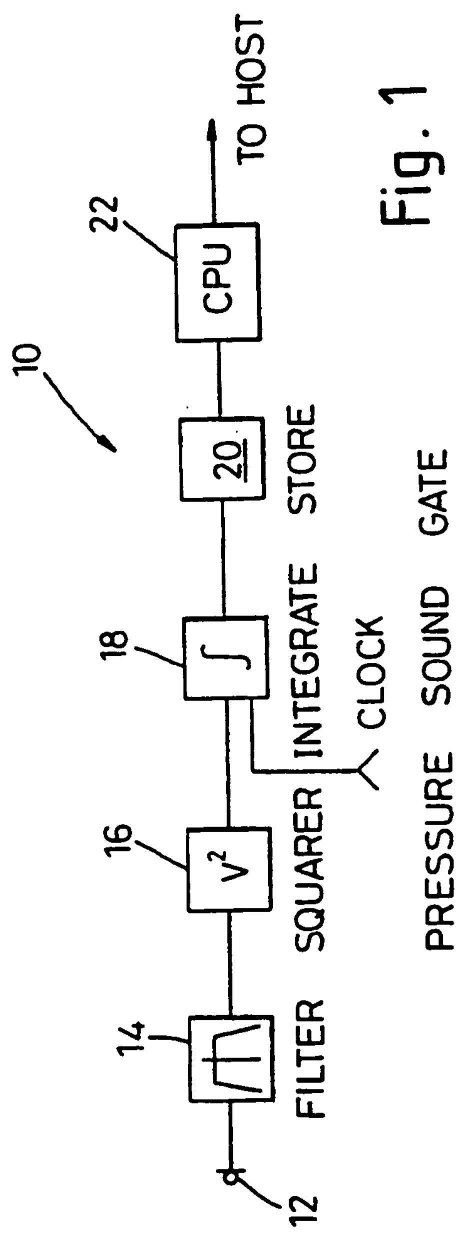
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Fig. 1

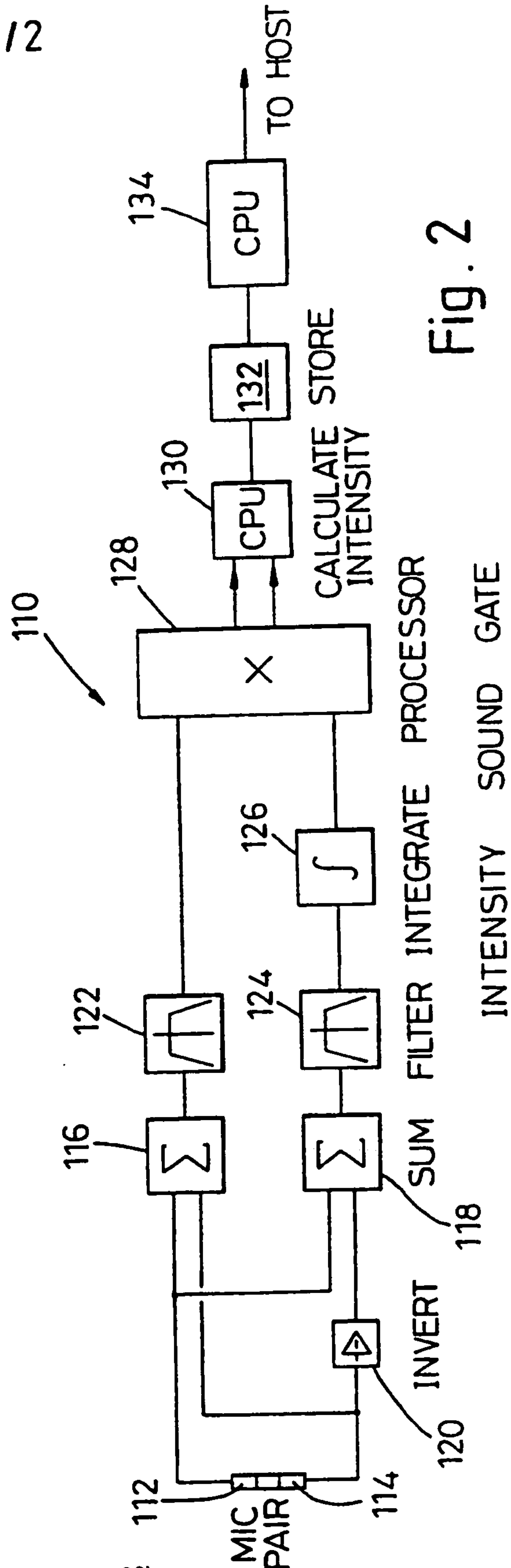
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Fig. 2

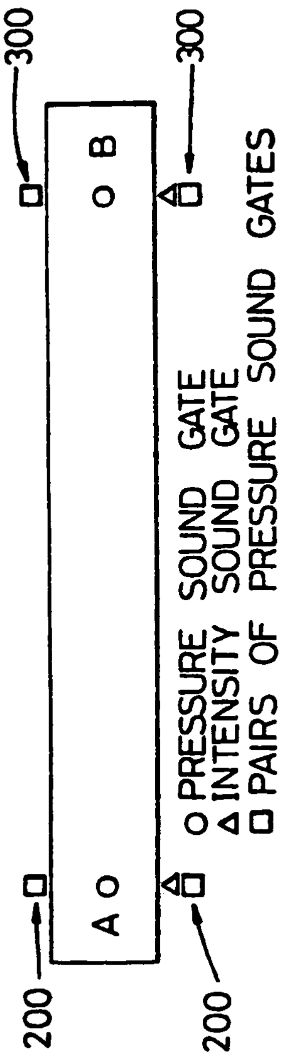

Fig. 3

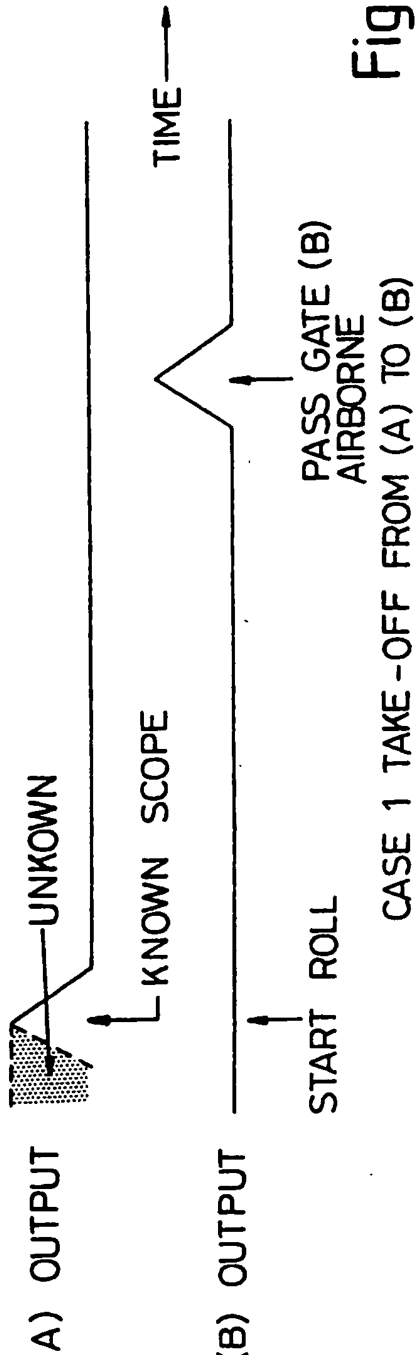

Fig. 4

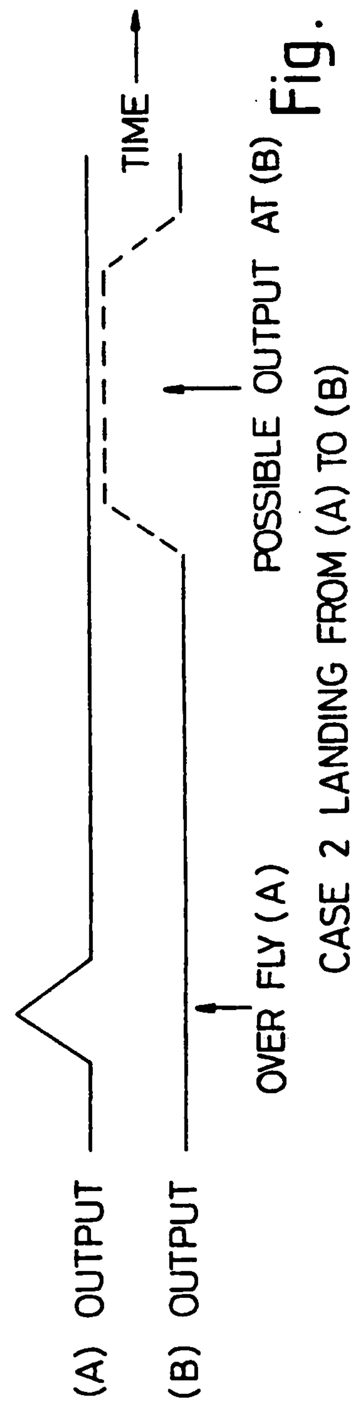

Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/00820

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V1/00 G01H3/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01V G01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB-A-2 235 771 (SECR DEFENCE) 13 March 1991 see abstract; claims 1,8; figure 5 ---	1,2,5,9, 11,12
X	J. WIGHT, P. DE HEERING, D. BALL, S. RADHAKANT 'Develpoment of a prototype aircraft counter- Phase I, A technical report prepared for the Transportation Development Centre, Montreal ,Quebec.' December 1987 , CANADIAN ASTRONAUTICS LIMITED , OTTAWA, CANADA see page 13-21 --- -/--	1,2,5,9

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
11 August 1995	18.08.95

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PCT/GB 95/00820

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NOISE CONTROL ENGINEERING, vol. 5, no. 1, July 1975 - August 1975 USA, pages 36-40, W. K. CONNOR, B. K. COOPER 'Automatic airport noise monitoring system' Paragraph: "Aircraft detection". see page 39; figure 6	1
A	US-A-3 855 571 (MASSA F) 17 December 1974 see abstract	1
A	PATENT ABSTRACTS OF JAPAN vol. 008 no. 179 (P-295) ,17 August 1984 & JP,A,59 072028 (KOBAYASHI RIGAKU KENKYUSHO;OTHERS: 01) 23 April 1984, see abstract	1
A	US-A-5 189 425 (HACKEL RICHARD P ET AL) 23 February 1993 see abstract; figures 9-11	8

INTERNATIONAL SEARCH REPORT

Inte[...]nal Application No
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		US-A-	5047995	10-09-91
US-A-3855571	17-12-74	NONE		
US-A-5189425	23-02-93	US-A-	5075680	24-12-91